Unitarity Triangle Fitter Results for CKM Angles

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Abstract

We present the status of the Unitarity Triangle analysis focused on the analyses connected to the CKM angles extraction. The angle values are found to be $\alpha = (90.6 \pm 6.6)^\circ$, $\sin(2\beta) = 0.68 \pm 0.023$, and $\gamma = (72.2 \pm 9.2)^\circ$.

1 Introduction

The Cabibbo-Kobayashi-Maskawa (CKM) matrix V_{ij} [1] has to be unitary, which implies several relations between its elements. In the Wolfenstein parameterizations [2], each of these relations can be represented as a triangle in the $(\overline{\rho}, \overline{\eta})$ plane. The triangles obtained by product of neighboring rows or columns are nearly degenerate. The particular interest is driven by the unitarity condition

$$V_{\rm ud}V^*_{\rm ub} + V_{\rm cd}V^*_{\rm cb} + V_{\rm td}V^*_{\rm tb} = 0, \tag{1}$$

with each item approximately proportional to λ^3. This equation is connected to B meson decays due to the presence of $V_{\rm ub}$ and $V_{\rm cb}$ matrix elements. Figure 1 shows the triangle, which angles, denoted by α, β, and γ, are[1]:

$$\alpha = \arg\left(\frac{V_{td}V^*_{tb}}{V_{ud}V^*_{ub}}\right), \beta = \arg\left(\frac{V_{cd}V^*_{cb}}{V_{td}V^*_{tb}}\right), \tag{2}$$

$$\gamma = \arg\left(\frac{V_{ud}V^*_{ub}}{V_{cd}V^*_{cb}}\right) = \pi - \alpha - \beta. \tag{3}$$

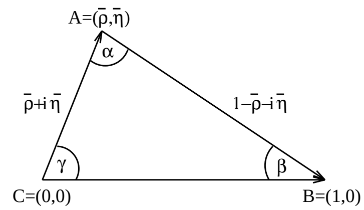

Figure 1: Unitarity Triangle in the $\overline{\rho} - \overline{\eta}$ plane.

These proceedings show the combination of angle measurement and their implementation as seen by the UTfit group [3]. The combination is performed in the Bayesian approach and uses the most recent results available by the time of the conference.

2 CKM angle α extraction

The CKM angle α is extracted from charmless hadronic B decays. We use the method described in [4]. The decays $B \to \pi\pi$ are analyzed using the SU(2) isospin symmetry to cleanly disentangle the penguin contribution. This method relates the isospin amplitudes of $B^0 \to \pi^+\pi^-$, $B^0 \to \pi^0\pi^0$, and $B^+ \to \pi^+\pi^0$ processes and their complex conjugates as two triangles in a complex plane. We use the CP-averaged branching fractions of the processes as well as the available time-dependent asymmetries. The input values are taken from HFAG [5]. The same procedure is applied to the $B \to \rho\rho$ system with an additional complication of a relative orbital angular momentum. A more complicated analysis is used to extract the angle α from the $B^0 \to \rho^0\pi^0$ decays. Here, we measure α using a time-dependent Dalitz analysis, which includes the variation of the strong phase of interfering ρ resonances.

Figure 2 shows the combination of the above mentioned methods. This combination gives $\alpha = (90.6 \pm 6.6)^\circ$.

3 CKM angle β extraction

The golden mode to measure the angle β is the $B^0 \to J/\psi K^0$ decay. This mode gives a value of $\sin(2\beta)$ which is considered practically free of theoretical uncertainties and thus serves as a benchmark for indirect searches for new physics. We estimate the deviation of the measured sine coefficient of the time-dependent CP asymmetry induced by the long-distance contributions from penguin contractions and by the

[1]Another notation for angles, which is also used, is $\phi_1 \equiv \alpha$, $\phi_2 \equiv \beta$, and $\phi_3 \equiv \gamma$. This notation is commonly used by Belle experiment.

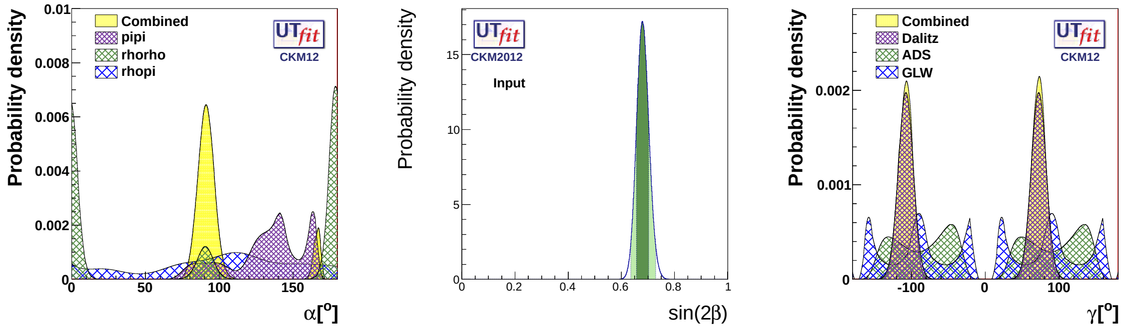

Figure 2: (color online) One-dimensional probability density functions for α (left), $\sin(2\beta)$ (middle), and γ (right) experimental results. The plots for α and γ also show the contribution from different channels and methods.

penguin operators using a data-driven technique [6]. Figure 2 shows the combination of all the information about the angle β. This combination gives $\sin(2\beta) = 0.68 \pm 0.023$.

4 CKM angle γ extraction

The CKM angle γ is one of the least precisely known parameters of the unitarity triangle. The methods of measurements [7, 8, 9] are using charged B meson decays into $D^{(*)}K^{(*)}$ final states which have no penguin contribution. This gives an important difference from most of other direct measurements of the angles. These processes are theoretically clean provided that hadronic unknowns are determined from experiment. The $\to \overline{u}s$ and $\to u\overline{c}s$ tree amplitudes are used to construct the observables that depend on their relative weak phase γ, on the magnitude ratio $r_B \equiv |\mathcal{A}(\to u\overline{c}s)/\mathcal{A}(\to \overline{u}s)|$ and on the relative strong phase difference δ_B between the two amplitudes.

The Atwood-Dunietz-Soni method [9] needs input from the D meson observables: amplitudes ratio r_D, strong phase difference δ_D, and coherence factor k_D. We perform a fit to the charm sector information allowing for CP violation in the singly-Cabibbo suppressed decays [10] and receive the following results that are used in the γ reconstruction: $\delta_D(K\pi) = (18 \pm 12)^\circ$ and $\delta_D(K\pi\pi^0) = (31 \pm 20)^\circ$. Combining the results obtained by LHCb, BaBar, Belle, and CDF collaborations we obtain $\gamma = (72.2 \pm 9.2)^\circ$.

The resulting combination is shown in Fig 2. We have also tested the influence of the prior probability distributions and found it to be negligible given the statistical uncertainty of the γ combination.

5 Overall Fits

Using the angle inputs and our Bayesian framework, we perform the fit to the information on angles to extract the CKM matrix parameters. We obtain $\overline{\rho} = 0.130 \pm 0.027$ and $\overline{\eta} = 0.338 \pm 0.016$. The resulting fit is shown in Fig 3. The fit precision can be improved by adding constraints on other parameters: $|V_{ub}|/|V_{cb}|$ from semileptonic B decays, Δm_d and Δm_s from $B^0_{d,s}$ oscillations, ϵ_K from K mixing. This approach yields $\overline{\rho} = 0.132 \pm 0.021$ and $\overline{\eta} = 0.348 \pm 0.015$. The results of the full fit are shown in Fig. 3. This approach also allows one to obtain the SM predictions for different observables. The comparisons to the predictions of the angle values are shown in Fig 4. The predictions for the angles are: $\alpha = (87.8 \pm 3.7)^{\circ}$, $\beta = (24.3 \pm 1.9)^{\circ}$, and $\gamma = (68.8 \pm 3.4)^{\circ}$. We do not see big discrepancies between the SM predictions and experimental measurements (for more information, see the web-site www.utfit.org).

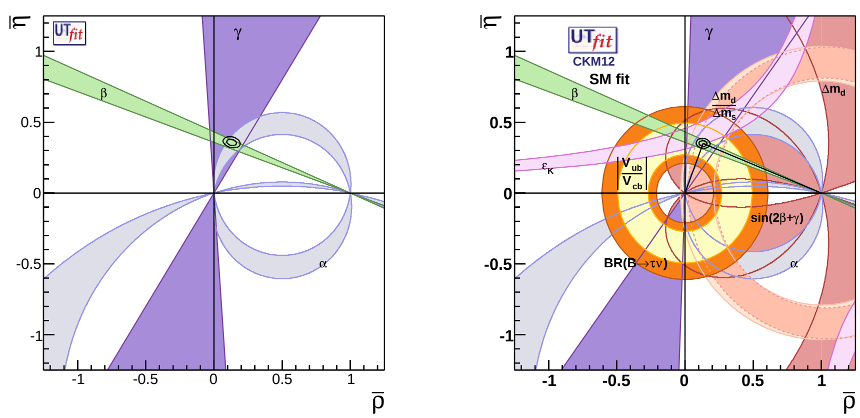

Figure 3: (color online) $\overline{\rho} - \overline{\eta}$ planes where the black contours display the 68% and 95% probability regions selected by the SM global fit. The 95% probability regions selected by the single constraints are also shown. Left: the angle-only fit. Right: the global SM fit using all the inputs described in the text.

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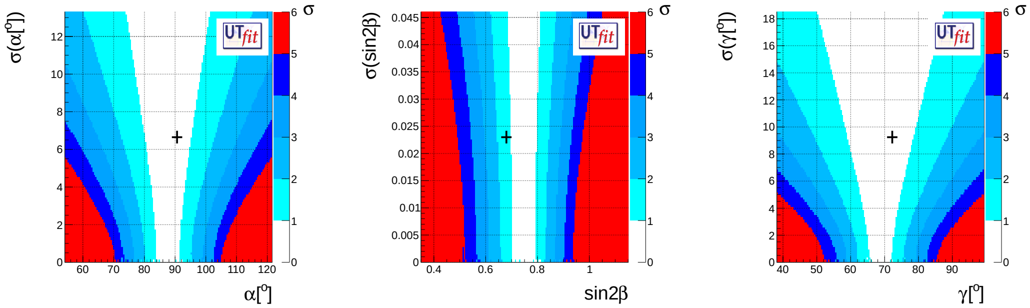

Figure 4: (color online) Compatibility plots for α, $\sin(2\beta)$, and γ.

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